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ON THE STUDY TO: DETERMINE IF DISTRIBUTION BOXES CAN BE ELIMINATED WITHOUT INDUCING INCREASED FAILURE OF DISPOSAL FIELDS

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Robert A. Taft Sanitary Engineering Center
Cincinnati, Ohio

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Final Report to

THE FEDERAL HOUSING ADMINISTRATION

On the Study to:

Determine if Distribution Boxes can be Eliminated Without Inducing Increased Failure of Disposal Fields

by

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February 19, 1958

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TABLE OF CONTENTS

Section	Page No.
CONCLUSIONS	1
ACKNOWLEDGMENTS	2
INTRODUCTION	3
DISTRIBUTION BOX HYDRAULICS	3
FIELD STUDY	5
St. Louis County, Missouri	7
Rapides Parish (Alexandria), Louisiana	8
Caddo Parish (Shreveport), Louisiana	9
ANALYSIS OF DATA	10
Validity of Comparison	10
Distribution of Factors Implicated in Failing Systems	12
PERFORMANCE COMPARED	17
Slope	17
Area and Subdivision	18
Overall Comparison	18
Survival Curves, St. Louis and Alexandria Combined	19
Long Term Experience Without Distribution Boxes	19
DISCUSSION	24
Engineering Significance	24
REFERENCES	26
APPENDICES	
A. DESCRIPTION OF SURVEY SITES AND RESULTS	27
St. Louis, Missouri	27
Alexandria, Louisiana	31
Shreveport, Louisiana	35
B. SAMPLE CALCULATIONS	38

CONCLUSIONS

1. Distribution boxes can be eliminated from septic tank soil absorption systems in favor of some other method of distribution without inducing increased failure of disposal fields. In fact, evidence indicates that distribution boxes as presently used may be harmful to the system.

2. Data indicate that on level ground, equal distribution is not necessary if the system is designed so that an overloaded trench can drain back to the other trenches before failure occurs.

3. On sloping ground a method of distribution is needed to prevent excessive build-up of head and failure of any one trench before the capacity of the entire system is utilized. It is doubtful that distribution boxes as presently used give equal distribution. Rather, they probably act as diversion devices sending most of the liquid to part of the system.

4. Before perfecting a device and increasing the control and extent of inspection required to accomplish equal distribution, the desirability of equal distribution over serial distribution should be established.

ACKNOWLEDGMENTS

The study described in this report is one of three sponsored by the Federal Housing Administration at the Robert A. Taft Sanitary Engineering Center. The other studies which are still in progress are concerned with the design of seepage pits and seepage beds.

A Board of Consultants consisting of:

Professor P. H. McGauhey, Director
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Mr. Clarence S. Slater
Soil Scientist
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assisted in planning the studies and in the review of progress and results. Mr. J. R. Simpson, Chief Sanitary Engineer, and Mr. Bernard T. Craun, Sanitary Engineer, F.H.A. participated in meetings with the consultants and provided liaison with the Federal Housing Administration.

Dr. Eugene K. Harris, Analytical Statistician, of the Sanitary Engineering Center participated in the meetings with the consultants. Much of the analysis of data is performed in Dr. Harris' statistical section under the immediate direction of Mr. Charles Zimmer, Analytical Statistician.

This report deals exclusively with a comparison of the performance of septic tank-soil absorption systems, some with and some without distribution boxes. Investigations were conducted from the St. Louis County, Missouri; the Rapides Parish (Alexandria), Louisiana; and the Caddo-Shreveport Parish, Louisiana Health Departments. The cooperation and assistance of these departments and the cooperation of the Louisiana and Missouri State Health Departments weighed heavily in the success of the study.

INTRODUCTION

Virtually all commonly accepted recommendations for septic tank-soil absorption systems insist on the use of a distribution box between the septic tank and disposal field. The generally accepted purpose of the box is to divide the flow from the septic tank equally among the several lines in the disposal field. The need for this division of flow is apparently based on two rational assumptions: (1) On sloping ground where elements of the system are installed at different elevations, some means of dividing flow is needed to prevent ponding in the lower portion of the system and subsequent seepage before the absorption capacity of the upper portion is utilized. (2) Based on experience with slow sand filters, it has been assumed that optimum use of absorption capacity can be obtained by spreading the load uniformly over the entire available area.

However, it has never been demonstrated that controlled distribution of flow can be obtained with a distribution box with reasonable care in construction. Likewise, the benefit of equal distribution has never been established.

DISTRIBUTION BOX HYDRAULICS

The outlet tiles from a distribution box may be considered as circular weirs or circular channels. As the slope of the tile increases, its flow characteristics approach those of a circular weir. At a slope great enough to eliminate backwater, flow into the outlet closely approximates weir flow. As the slope of tile decreases, its flow characteristics approach those of a circular channel. The effect of differences in head on volume of flow are greater in channel flow than in weir flow.

Assuming that a distribution box has two or more outlets to divide the incoming flow, the effect of differences in heads on the outlets (or differences in elevation of the outlets) may be demonstrated theoretically by considering the outlets as circular weirs.

Approximate discharge rates for the common household plumbing fixtures, and the heads these rates would develop in a two outlet distribution box with inverts set at exactly the same elevation, are shown in Table 1. With a greater number of outlets, the flow through each outlet and thus the head which would develop would reduce proportionately.

Table 1

Rate of Flow and Theoretical Head Developed in the Distribution Box for Various Household Plumbing Fixtures

Fixture	Discharge Rate		Head developed in distribution box for equal flow inches
	To plumbing gpm	To one line of a two line disposal field gpm	
Washbasin-water running	0.75	.38	1/4
Kitchen sink-dishwash rinse	1.50	.75	3/8
Shower	3.50	1.8	1/2
Washing machine	10.0	5.0	7/8
Bathtub draining	15.0	7.5	1 1/8
Sump pump	30.0	15.0	1 5/8

A toilet flush will produce a flow of approximately 50 gpm, but it is of such short duration and of such small volume that the effect would be lost at the distribution box.

In these calculations it has been assumed that there is no dampening effect of flow through the house plumbing, sewer, and septic tank. In actual practice the dampening effect would reduce the maximum heads developed and make differences in outlet elevations even more critical.

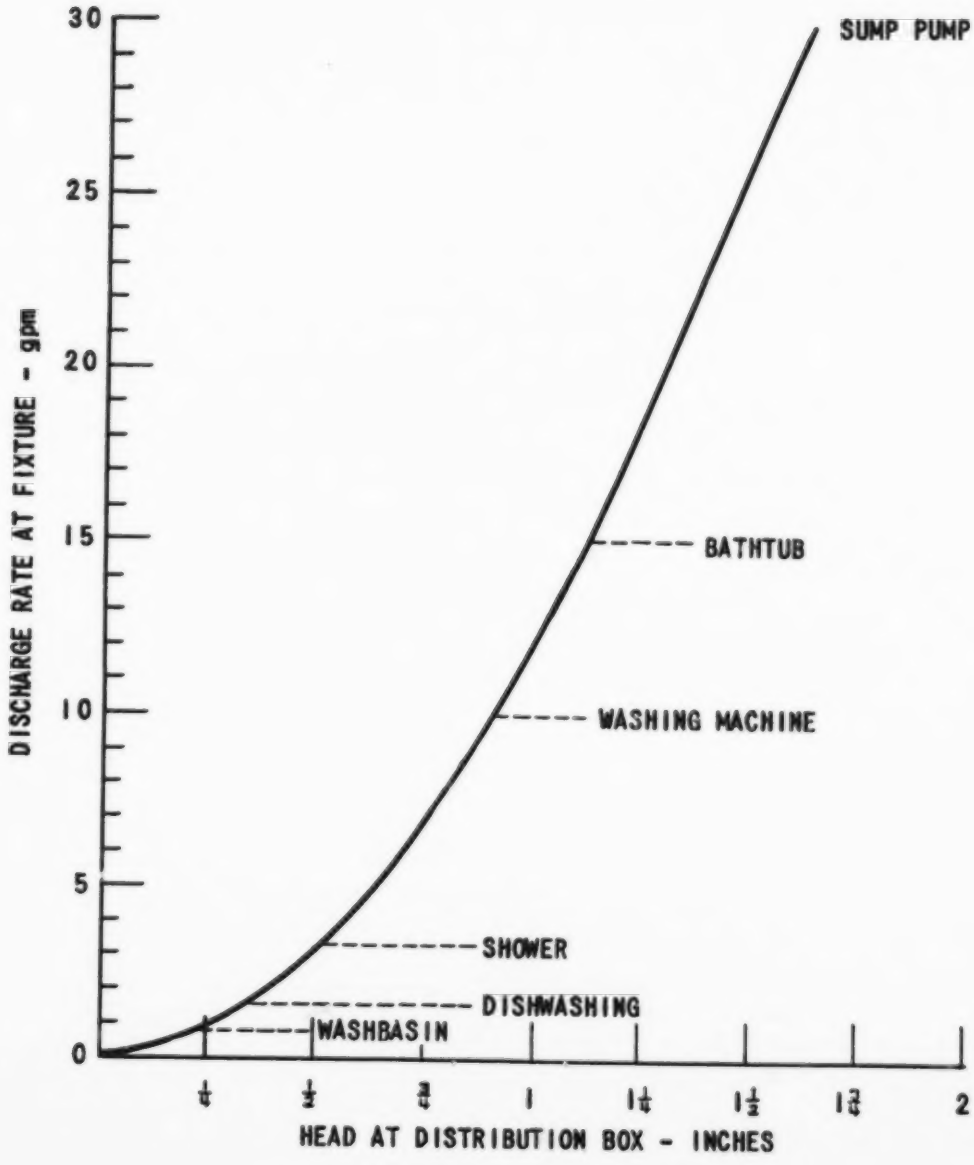
Head calculations are based on the Greve(1) circular weir formula, as applied to a four-inch diameter weir.

$$h = .38\ q^{.535}$$

h = head in inches

q = weir discharge in gal/min

A plot of q versus h for a distribution box with two four-inch diameter orifices is shown in Figure 1.



HEAD VS. DISCHARGE RATE

Figure 1

The calculated discharge rates and heads at the distribution box outlets illustrate the necessity of outlet elevations being exactly level in order to obtain equal distribution. Flow from most of the household plumbing fixtures develops heads at the distribution box of less than one inch. A difference of one inch in the elevation of two outlets of a distribution box would thus result in all of the flow going to the lower line. A difference of 1/4 inch in the elevations would result in 3/4 of the flow going to the lower line. With more than two outlets in a distribution box, heads developed are smaller and differences in elevation become even more critical.

If the above flow and head calculations are made on the basis of channel flow rather than weir flow, discharge shows a much greater response to change in head and it can be demonstrated that critical differences in elevation become even smaller.

It is therefore evident that accurate construction and careful control are necessary if a distribution box is to accomplish equal distribution. It is also evident that unless the box is installed with the utmost care it will in effect become a diversion box and may promote early failure in an otherwise adequate system.

FIELD STUDY

In some areas of the country systems are installed without the distribution box and in other areas a change in practice resulted in an era in which distribution box and other types of systems were being installed at the same time. These conditions permitted a study to accomplish the objectives in two ways.

1. A direct comparison of failure rates in areas where both types of systems had been installed.

2. Studying the performance of systems without distribution boxes by a survival type performance curve in an area where "no distribution box" systems have been used for many years.

The areas selected for study presented a variety of climatic and terrain conditions, but the northern portion of the country where freezing and frost heaval is reported to disrupt the performance of distribution boxes was avoided. If the results of this first investigation had been different, a further investigation of climatic conditions unfavorable to the distribution box would have been justified.

The general survey technique was used for the entire study. With the assistance of PHS Region offices and State Health Departments, and local health departments, general areas were selected for study. Emphasis was placed on the existence of the type of systems in question for sufficient time to develop a pattern of performance, the adequacy of records, and the assurance of cooperation and assistance.

An engineer was stationed at the health department and advance publicity was obtained in the press and radio whenever possible. The engineer was provided with identification and the authorities of towns and villages that might be entered were notified of the operation. Assistance was sought and obtained in some instances from local offices of the Federal Housing Administration and local home builders' associations.

In general, within the county or parish, specific areas were chosen for study, taking into consideration age of homes, type and uniformity of homes, number of systems available for study, and the amount of preliminary information that could be obtained from the county files. Sanitarians and plumbing inspectors, F.H.A. offices, builders and builders' associations, septic tank installers and cleaners, soils maps, and general maps were the important sources of information in selecting a specific area for study.

Although the study was not confined to them, large subdivisions or areas developed by a limited number of builders proved fruitful from these considerations. A recorded plat of the subdivision was obtained to provide the approximate street addresses for a search of the health department files. In some instances, phone books, city directories, utility company records, and old tax records were used to associate names and addresses with installation permits.

Preliminary information showing the type and location of the system was entered on a separate data sheet for each home. With the aid of the plat or a map, lot numbers were related to house numbers and the sheets were arranged by street and house number preparatory to the door to door survey.

An attempt was made to obtain information from the occupants of every house on which a preliminary data sheet had been drawn. Before giving up on cases where no one was at home on the original call, one Saturday and two additional week-day calls were made. The surveyor did his best to obtain an accurate record of performance and load in terms of persons, appliances, etc. at each home. The occupant was questioned concerning the operation of the system, and the surveyor inspected the area of the disposal field for indications of present or past failure before passing judgment.

Two criteria, surface seepage or sluggish fixtures, were used to determine failure. A failure was recorded if there was [illegible] surface of the disposal field, or if there was a history of sluggish or inoperative fixtures. In the second case, care was taken to determine that a mechanical stoppage of drain lines was not involved. In the case of a failure, the date of its first occurrence was established as closely as possible.

The completed data sheet contains a description of the system, a record of the load applied, and a history of its performance.

St. Louis County, Missouri

St. Louis County, Missouri was selected for the initial site of the study, and Senior Assistant Sanitary Engineer, Warren F. Smith, was assigned to the area on April 4, 1957. Mr. George Borgstede, registered professional engineer, was retained to assist Mr. Smith. Before entering private practice, Mr. Borgstede was employed in the St. Louis County Health Department and is well acquainted with personnel and procedures.

As early as the Spring of 1954 Dr. H. R. Domke, Commissioner of Health, and Mr. H. C. Mitchell, Director of Sanitation, had urged a study of the necessity for the distribution box. In addition to the early interest, St. Louis was an ideal location for the study in a number of other respects.

Under the direction of Dr. Domke, Mr. Mitchell is responsible for sanitary engineering and sanitation services. The County is divided into a north and a south district with a staff of inspectors and a Sanitarian Supervisor and a Sanitary Engineer for each district.

Practice in St. Louis County has varied considerably in the past ten years. Requirements governing the installation of septic tank systems have become more stringent, and control and inspection of systems have tightened as the growth of the County produced a sewage disposal problem of increasing magnitude. A comprehensive septic tank ordinance passed in 1954 has been conscientiously applied. Where several methods of distribution were used before 1954, the ordinance specified distribution boxes and that method is now used almost exclusively. As a result, distribution box systems were scarce before 1954, and other types have been scarce since then.

Until 1954 almost all systems used either:

a. T's branching off of one main discharge line from the tank.

b. Headers, using one sealed line from the tank and laterals at right angles to the header line.

c. So called "land blocks" on sloping ground. Several trenches at different elevations are connected by an overflow line at an elevation near the top of the higher trench. In this manner, the upper trench is full before the succeeding lower trench receives any effluent.

In practically all cases, 500 gallon single compartment septic tanks and 400 square feet of absorption area were used prior to 1954. Under the new regulation, absorption area is determined by means of the percolation test, and 400 square feet is the minimum.

Although it was relatively difficult to find a common era for comparison, seven subdivisions were found where distribution boxes and other types of systems had been installed simultaneously. Plats of the seven subdivisions were obtained and using the records, a survey sheet was made for each lot showing the type and the size of the system used. A door-to-door survey was then made to obtain the history of operation by interview and inspection.

A description of the seven subdivisions surveyed and the results obtained are contained in Appendix A.

Rapides Parish (Alexandria), Louisiana

On June 10, 1957, Mr. Smith reported to the Rapides Parish Health Department at Alexandria, Louisiana. Under the direction of Dr. Kenderick Taylor, Parish Health Officer, Mr. Dewey Richardson, Chief Sanitarian, is responsible for the approval and inspection of septic tank systems.

Records of septic tank installations were available back to 1952. From 1952 to 1954 a 500 gallon single compartment circular metal septic tank and 200 linear feet of 18 inch trench was the standard system. In some instances, laundry waste by-passed the tank and went directly to the field. It was also common to pass kitchen waste through a separate grease trap and by-pass the septic tank.

From 1954 to present, a 600 gallon circular metal tank and 300 linear feet of 36 inch trench has been standard. Washing machines and kitchen sinks are now discharged to the septic tank.

Percolation tests are not made on individual sites, although tests are often made on a subdivision basis.

From 1952 to 1954 most systems had distribution boxes; however, some systems (usually with only two lines) used tees. After 1954 with the increased area requirement practically all systems have distribution boxes.

The areas studied in Rapides Parish are all on level ground and the majority of complaints stemmed from poor surface drainage. After prolonged periods of rain, the water table rises, the ground reaches saturation and there are complaints of sluggish or inoperative fixtures. It was reported that this condition clears up after one or two days of dry weather. In judging failures a distinction was made between the wet-weather difficulties and dry weather failure with only the latter counting for the purpose of this study.

Initially the purpose of the Alexandria study was to find cases with distribution boxes that could be compared with systems installed without distribution boxes in Shreveport. Both Alexandria and Shreveport are located on the Red River and have some soil groups as well as climatic and other factors in common. With the Shreveport comparison in mind, subdivisions on Miller very fine sand loam and Miller silt loam were surveyed. After the study developed, enough non-distribution box systems were found to permit a direct comparison in the Alexandria area.

A description of the 12 subdivisions and the results obtained are contained in Appendix A.

Caddo Parish (Shreveport) Louisiana

On July 16, 1957 Mr. Smith reported to Shreveport to commence the Caddo Parish Survey. In August he was transferred to another assignment and left the project. Mr. A. J. Muhich was moved from the seepage bed study early in September to replace Mr. Smith, and arrangements were made to recall Mr. Smith for two weeks to work with Mr. Muhich. By providing the two week overlap, the difference in results due to the human element in judging failures was reduced to a minimum.

Under the overall supervision of Dr. W. J. Sandidge, Caddo Parish Health Officer, Mr. Floyd Miller, Chief Sanitarian, Mr. Percy Eakin, Assistant Sanitarian, and the sanitarian staff handle all septic tank inspections in Shreveport and Caddo Parish.

Records of installations have been maintained from 1937 to the present time.

Installation requirements have been uniformly maintained during this period, with the standard installation being a single compartment concrete tank of 720 gallons liquid capacity, and 250 to 300 feet of tile field in a one foot trench prior to 1950 and in an 18 inch trench after that time. Except for very unusual cases (usually commercial or institutional), no distribution boxes have been used. The absorption fields have been laid out with a series of tees and/or wyes. Starting in 1952, it has become increasingly customary to require from 50 to 100 feet of separate disposal field for the washing machine.

Percolation testing of soil was started in 1953 and is now required in all cases. Three test holes are used for each lot, including those in subdivisions.

During the period from 1937 to 1950, all possible cases on which complete records were available were selected, regardless of their location in the Parish. From 1951 to late 1956, only those cases in the areas previously used were selected, and no new subdivisions were taken.

Therefore, the overall selection method results in a comparison of cases in specific but unrelated areas over a 20 year period of time and covers subdivisions which were developed slowly over a period of many years. Out of 609 inspections, a total of 110 failures were observed. Surveys were conducted in the subdivisions described in Appendix A.

ANALYSIS OF DATA

Validity of Comparison

Many factors other than the use of a distribution box affect the performance of septic tank systems. A bias produced by any one, or a combination of these other factors favoring one system over the other, could produce misleading results. By working in subdivisions within the jurisdiction of a local health department, the chances of maintaining equality on such factors as age, soil, area, control, construction and climatic conditions were enhanced.

To investigate the possibility of bias further, an analysis was made to find significant factors in failing and non-failing systems. A separate analysis was made for each factor suspected of influencing the operation of the systems. Systems with the factor were separated from those without, and a further breakdown between failing and non-failing systems was made as shown in the following example.

Distribution of Dishwashers

	Total	Satisfactory	Failed	Percent Failed
Systems with dishwashers	159	131	28	17.6
Systems without dishwashers	1458	1130	328	22.5

Although the percent failure (17.6%) is lower in systems with automatic dishwashers than in those without (22.5%), the chi-square test shows that there is insufficient reason to believe that the use of dishwashers affects the failure rate.

Influence of Factors on Performance

Factor	Effect
Additives	No significance
Alteration to topography	Significant, high failure in cut and fill
Area of system	Significant, low failure in middle range of areas
Dishwasher	No significance
Economic class	Significant, higher failure in lower class
No. of fixtures	No significance
Garbage grinder	Significant, higher failure with grinder
Person loading	Significant
Section of country	No significance
Slope of land	Significant, high failure on slopes
Soil type	Significant, low failure in "fair" soil
Systems cleaned	Significant but cleaning and failure are correlated with cleaning a remedial action following failure

The data were further analyzed to determine if the items implicated in high failure rates were distributed equally between the distribution box and non-distribution box systems. Results of the analysis are summarized as follows.

Distribution of Factors Implicated in Failing Systems

Alteration of Topography

Alexandria--all systems on flat ground with no significant alteration

St. Louis--by subdivision Concord Meadows and Crestshire had a disproportionate number of distribution boxes on cut and fill ground. On the whole, however, a greater proportion of "other" type systems were installed in "cut and fill" ground and the difference was significant.

All of St. Louis

	D.B.	Other		
Undisturbed	191	152	343	chi square = 7.2
Cut or fill	27	45	72	
	218	197	415	

Area

Distribution of Observations by Square Feet of Absorption Area per Person

Area Sq Ft Per Person	Number of Observations			
	St. Louis		Alexandria	
	D.B.	Other	D.B.	Other
0 - 99	44	35	44	50
100 - 199	124	58	166	30
200 - 299	24	12	17	0
300 - 399	4	0	11	3
400 - 499	0	0	1	0
Average Area Ft^2/person	137	127	152	105
Chi Square	5.95		54.6	
Probability	.80		<.01	

The average per capita absorption area was greater in both cities for the distribution box system, but for St. Louis the difference was not significant.

Economic Class

In Alexandria all of the houses examined were in the middle or upper middle class. St. Louis contained houses in the lower price range only in Castle Point and the number of distribution box systems was significantly higher than the number of "other" systems. However, a review of Castle Point data show that this subdivision did not have a high failure rate and did not contribute to the significantly higher gross failure rate observed for houses in the lower price range.

All of St. Louis

	D.B.	Other		
Low	31	12	43	chi square = 6.56
Middle & High	187	185	372	
	218	197	415	

Garbage Grinder

In Alexandria there were very few distribution box systems with garbage grinders and none were failing. In St. Louis there was no difference in the frequency of occurrence in the two types of systems.

	D.B.	Other		
With G.G.	39	25	64	chi square = 1.81
Without G.G.	179	172	351	
	218	197	415	

Laundry Loads Per Week

There was no significant difference in the laundry load on the two types of systems

Loads Per Week	St. Louis		Alexandria	
	D.B.	Other	D.B.	Other
None	11	0	10	9
1 - 5	62	47	56	17
6 - 10	76	39	120	40
11 - 15	18	8	35	12
16 - 25	9	3	10	4
Average	6.9	6.4	7.7	7.4
Chi-Square	0.98		4.9	
Probability	.09		.55	

Person Loading

Average person loading was substantially equal in all cases.

	Average Number of Persons	
	D.B.	Other
St. Louis	4.34	4.23
Alexandria	3.87	3.93

The distribution of person loading was further investigated on a subdivision basis in St. Louis and found to be non-significant.

Subdivision	Average Person Loading D.B.	Other	All Systems
Assum. Valley	4.7	5.1	4.8
Burke City	4.4	4.7	4.6
Capitol Hills	3.2	4.2	3.7
Castle Point	4.3	3.8	4.1
Concord Meadows	4.7	4.9	4.8
Crestshire	3.8	4.2	4.0
Ferguson Acres	3.2	3.7	3.4

Slope of Ground Surface

All systems in Alexandria were installed on relatively flat ground.

% Slope	St. Louis Number of Observations D.B.	Other	Total
None	83	49	132
1.0	60	24	84
2.0	39	37	76
3.0	8	9	17
4.0	2	1	3
5.0	13	25	38
6 - 10	5	5	10
Over 10	8	47	55

Fewer distribution box systems were installed in steeply sloping ground and more of them were installed in level ground than the other type systems. Thus the performance of the distribution box systems was favored.

Soil

All systems in Alexandria were in soil judged to be good. In St. Louis, a slightly larger proportion of the distribution box systems were in good soil and a smaller proportion were in poor soil.

St. Louis

Type of System	Number			Percent		
	Good	Fair	Poor	Good	Fair	Poor
D.B.	11	157	52	5.0	71.4	23.6
Other	17	282	171	3.6	60.0	36.4

Chi square = 10.6

Septic Tank Capacity

As shown in the following tabulation, the distribution box systems were provided more capacity per person than the "other" type systems.

Capacity Gals per person	Number of Observations			
	St. Louis		Alexandria	
	D.B.	Other	D.B.	Other
0 - 99	45	56	18	21
100 - 199	130	99	193	47
200 - 299	35	41	10	12
300 - 599	5	0	18	3
Average Capacity Gals per person	149	139	148	138
Chi square	9.9		31.8	
Probability	.02		<.01	

Summary

On the basis of alteration of topography, absorption area, slope of ground, soil classification, and septic tank capacity, the performance of distribution box systems was favored. More low price range houses were served by distribution box systems than by other types. However, this difference was caused by one subdivision and performance of distribution box systems was relatively good in that subdivision.

Thus, the data were not exactly comparable, but the bias is in favor of the distribution box systems.

PERFORMANCE COMPARED

Slope

Systems on ground with a slope equal to or less than 4 percent were judged to be on relatively flat ground, and those on slopes greater than 4 percent were judged to be in a critical category. Furthermore, in that the "land-block" system represented a serial rather than equal type of distributing method, the land-block systems were separated from the other types for an evaluation of the effect of slope.

Table 2

Effect of Slope on Performance

Number of Observations

	Distribution Box		Other Types		Land Block	
	% Slope		% Slope		% Slope	
	0 - 4	Over 4	0 - 4	Over 4	0 - 4	Over 4
Satisfactory	163	12	76	16	24	29
Failed	29	14	15	12	3	22
Percent Failing	15	54	16	43	11	43

It is apparent that the failure rate of all types of systems is higher on sloping ground, and the distribution box is not effective in reducing the failure rate. In part at least, the high failure rate on sloping ground is attributable to systems installed in cut or filled ground.

Area and Subdivisions

Although a total of 697 systems were examined in the seven subdivisions studied in St. Louis, Missouri, only 415 are used in the following table in order to keep time in service on an equivalent basis. Column P is the probability of obtaining a difference in failure rates as large or larger than that observed if no true difference actually exists. In the cases of Assumption Valley and Alexandria, P was taken from a table of chi-squares. Because of the small numbers in one or more of the boxes for the 4-fold tables (See Appendix A), P for other areas was computed by an "exact" method[1]. Sample calculations are shown in Appendix B.

Table 3

Direct Comparison of Performance Within Areas at Equivalent Time in Service

Location	Age of Systems Yrs	With Boxes		Without Boxes		Significance		
		Total No. of Systems	Percent Failing	Total No. of Systems	Percent Failing	Std. Dev. %	Chi-Square	P
St. Louis, Mo.								
Assum. Valley	0-3	31	35	15	40	15	.002	.34
Burke City	1-3	112	7	46	4	4	.080	.64
Capitol Hills	1-3	11	0	19	21	13	---	.14
Castle Point	1-3	31	23	11	27	15	.096	.78
Concord Meadows	3	15	80	15	60	17	.635	.22
Crestshire	7-8	13	15	19	16	13	.217	.68
Ferguson Acres	6-7	5	60	72	53	23	.440	.26
Alexandria, La.	0-5	236	27	86	31	6	.206	.33

Overall Comparison

The exact probabilities were combined using the relationship $u = -4.6052 \{ \log P_1$, to obtain an overall probability for the data. For the 7 subdivisions in St. Louis "u" is equal to 14.0, or from a table of chi-square with 14 degrees of freedom, it is seen that the probability is 0.46 of obtaining by chance alone results showing a greater difference in performance than that observed. St. Louis and Alexandria data combined result in a probability of 0.44.

On the basis of these data there is little reason to reject the hypothesis that there is no true difference in performance of the distribution box and non-distribution box systems either on an individual subdivision or an overall basis.

Survival Curves, St. Louis and Alexandria Combined

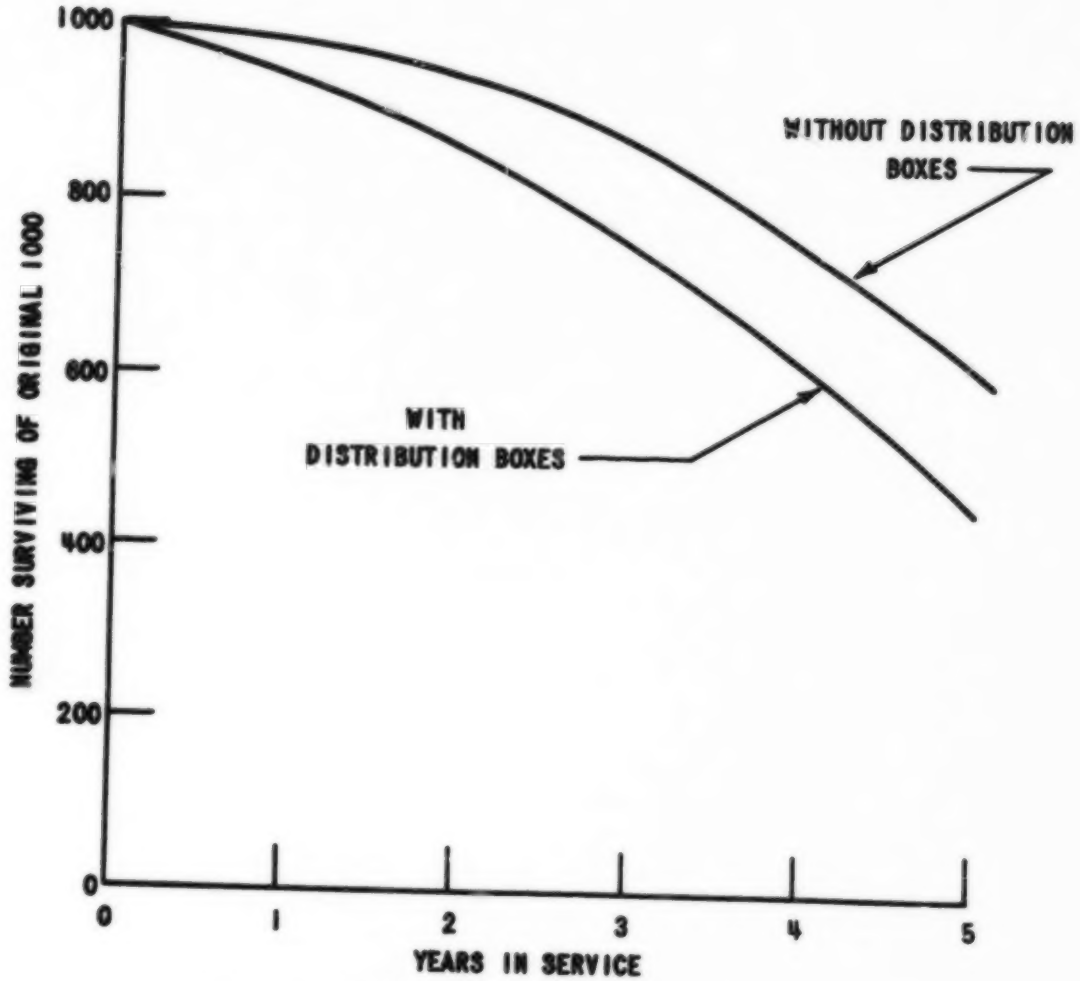
The foregoing treatment compared systems on the basis of areas and subdivisions, but time in service ranged over a period of several years. To compare the two systems in groups of equal age, and to show the cumulative effect of early failure rates, a survival type life table was prepared. The data for St. Louis and Alexandria were combined and separations by type of system and age groups were made. Failures were recorded at the age of occurrence. The calculations for arriving at the curves on Figure 2 are shown in Tables 4 and 5. Data for Ferguson Acres and Crestshire have been omitted in order to provide a continuous spectrum of observations. Inclusion of the two older subdivisions does not alter the relative position of the curves, but causes a deformation in the distribution box curve that detracts from the comparison.

No attempt has been made to establish the significance of the apparent improvement of performance of the "other" systems over that of the distribution box systems. It is evident, however, that the true experience with the distribution box could not be better than that of the "other" type systems.

Long Term Experience Without Distribution Boxes

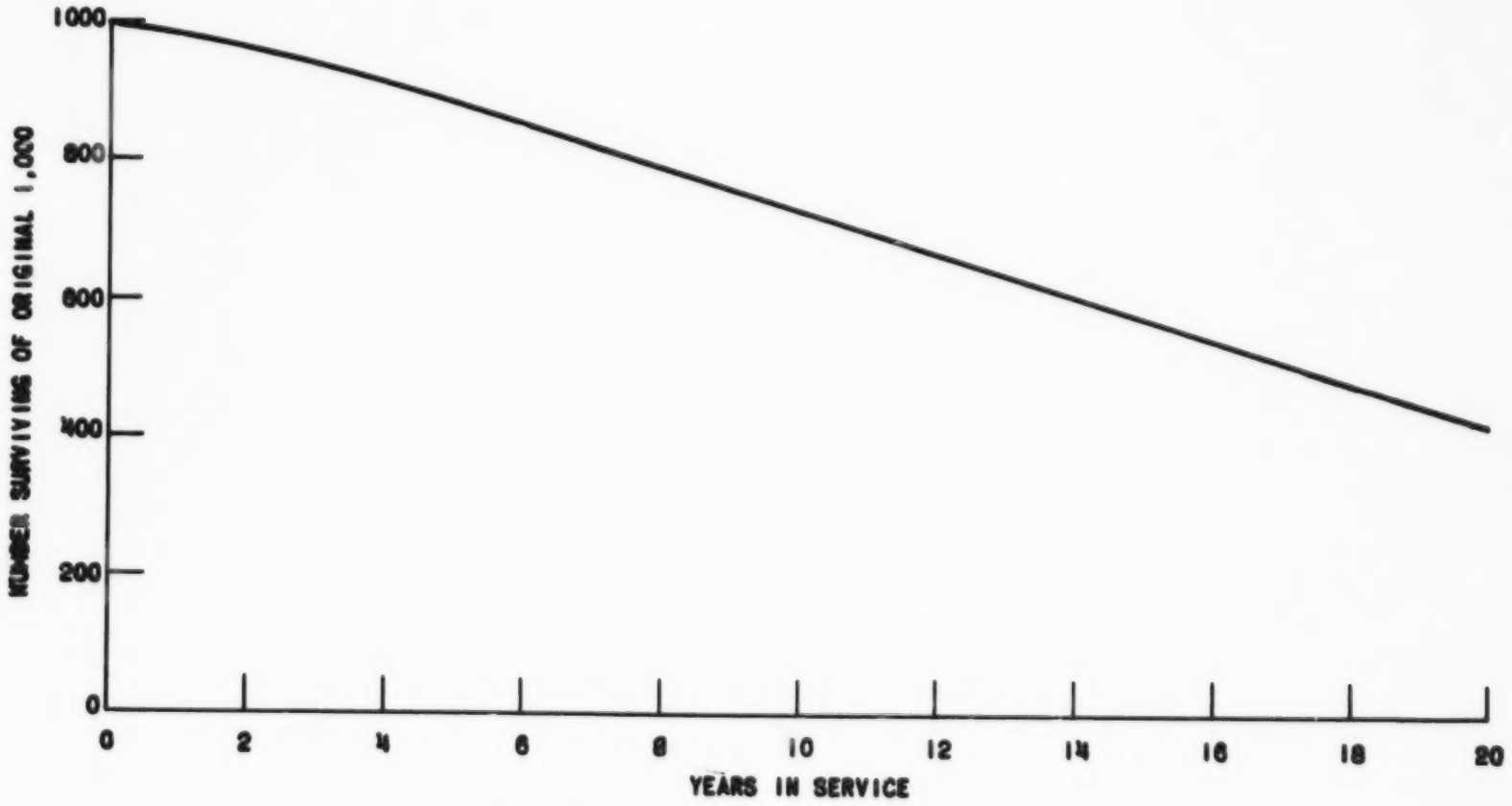
Data from St. Louis and Alexandria permit a direct comparison of systems with and without distribution boxes during the early years in service. However, with the exception of two subdivisions, Ferguson Acres and Crestshire, no areas could be found where both types were used simultaneously for more than 5 years. Thus, although the evidence for early performance is quite conclusive, data from Alexandria and St. Louis shed no light on the question of long term performance.

Shreveport, Caddo Parish, Louisiana presented an opportunity to study the performance of systems that had been in use for as long as 20 years without benefit of distribution boxes. Data are arrayed in Table 6 to show the total number of systems in a given age bracket and the time distribution of failures. These data are summarized in Table 7 and the resulting survival curve is shown on Figure 3.



SURVIVAL CURVES – ALEXANDRIA AND ST. LOUIS

FIGURE 2



SURVIVAL CURVES SHREVEPORT, LOUISIANA
Figure 3

Table 4

Distribution Box Systems, St. Louis and Alexandria
Survival Curve Calculations

Age Interval Yrs	No. of Install-ations	Number of Systems Failed During Age Interval				
		0 - .9	1.0 - 1.9	2.0 - 2.9	3.0 - 3.9	4.0 - 4.9
0 - .9	61	5				
1.0 - 1.9	216	12	33			
2.0 - 2.9	115	3	1	29		
3.0 - 3.9	16				6	
4.0 - 4.9	32	1				8
Total	440	21	34	29	6	8

Age of System	Number Reaching Age	Number Failed	q_x	l_x	d_x
0 - .9	440	21	.048	1000	48
1.0 - 1.9	363	34	.094	952	90
2.0 - 2.9	158	29	.183	862	157
3.0 - 3.9	47	6	.127	705	90
4.0 - 4.9	31	8	.258	615	159
5.0 - 5.9				454	

Table 5

Other Type Systems, St. Louis and Alexandria
Survival Curve Calculations

Age Interval Yrs	No. of Install-ations	Number of Systems Failed During Age Interval				
		0 - .9	1.0 - 1.9	2.0 - 2.9	3.0 - 3.9	4.0 - 4.9
0 - .9	1	0				
1.0 - 1.9	12		1			
2.0 - 2.9	93	5	1	24		
3.0 - 3.9	163	10		2	39	
4.0 - 4.9	95	2		1	1	15
Total	364	17	2	27	40	15

Age Interval Yrs	No. of Systems Entering Interval	Number Failing in Interval	q_x	l_x	d_x
0 - .9	364	17	.047	1000	47
1.0 - 1.9	346	2	.006	953	6
2.0 - 2.9	333	27	.081	947	77
3.0 - 3.9	243	40	.165	870	143
4.0 - 4.9	91	15	.165	737	122
5.0 - 5.9				615	

Table 6

Other Type Systems, Shreveport, Louisiana
Survival Curve Calculations

Age Interval Yrs	No. of Installations	Age at Failure - Yrs																
		0 to .9	1.0 to 1.9	2.0 to 2.9	3.0 to 3.9	4.0 to 4.9	5.0 to 5.9	6.0 to 6.9	7.0 to 7.9	8.0 to 8.9	9.0 to 9.9	10.0 to 10.9	11.0 to 11.9	12.0 to 12.9	13.0 to 13.9	14.0 to 14.9	15.0 to 15.9	16.0 to 16.9	17.0 to 17.9
0 - .9	3																	
1.0 - 1.9	51	3																
2.0 - 2.9	85	2	2	2														
3.0 - 3.9	69	2	4		3													
4.0 - 4.9	66	1	3	1	2	2												
5.0 - 5.9	71		3		4	1	1											
6.0 - 6.9	58		1	3	2	2	4	5										
7.0 - 7.9	59	1		1	1	3	2		3									
8.0 - 8.9	57	2	1		1	1	2	2	1	3								
9.0 - 9.9	20		1				1	1	2									
10.0-10.9	10									1		3						
11.0-11.9	2										1							
12.0-12.9	2				1													
13.0-13.9	4										1		1		1			
14.0-14.9	4														1			
15.0-15.9	7											1						
16.0-16.9	18					1	1					2				3		1	
17.0-17.9	14					1		1					1			1			1
18.0-18.9	3																	1	1
19.0-19.9	5																1		
20.0-20.9	1																		
Total	609	11	15	7	14	11	11	9	6	4	2	6	2		2	4	1	2	2

Table 7

Age Interval Yrs (1)	No. of Systems Entering Interval (2)	Number Failing During Interval (3)	q_x (4)	l_x (5)	d_x (6)
0 - .9	609	11	.018	1000.	18
1.0 - 1.9	595	15	.025	982.	25
2.0 - 2.9	532	7	.013	957.	12
3.0 - 3.9	446	14	.031	945.	29
4.0 - 4.9	372	11	.030	916.	28
5.0 - 5.9	304	11	.036	888.	32
6.0 - 6.9	231	9	.039	856.	33
7.0 - 7.9	181	6	.033	823.	27
8.0 - 8.9	127	4	.031	796.	25
9.0 - 9.9	79	2	.025	771.	19
10.0-10.9	62	6	.097	752.	73
11.0-11.9	50	2	.040	679.	27
12.0-12.9	47	0	000	652.	0
13.0-13.9	46	2	.043	652.	28
14.0-14.9	43	4	.093	624.	58
15.0-15.9	36	1	.029	566.	16
16.0-16.9	29	2	.069	550.	38
17.0-17.9	17	2	.118	512.	60
18.0-18.9	6	0	000	451.	0
19.0-19.9	5	0	000	441.	0
20.0-20.9	1	0	000	441.	0

q_x = failure rate for interval = $\frac{\text{Col.(3)}}{\text{Col.(2)}}$

d_x = number failing during interval = Col.(4) x Col.(5)

l_x = number of systems surviving at start of age interval

Because of differences in tank capacities, absorption areas, and loading of the system, Shreveport is not directly comparable with the other two areas. However, the curve illustrates that systems without distribution boxes can be designed for a long period of operation. There is smooth transition with no breaks or sharp dips in the survival curve during the late years.

DISCUSSION

The study was conducted in areas where a wide range of soil, topography, and usage were encountered, but where climatic conditions did not represent a special hazard to distribution boxes. If the distribution box registered a higher level of performance it was understood that further investigation would be necessary in climates unfavorable to the box. As it developed, it is believed that the conclusions are applicable on a nation-wide basis.

A preponderance of evidence indicated that the success of distribution box systems was favored in factors that were judged to be important to the performance of the soil absorption system. Without eliminating this bias, systems were compared on the basis of topography, location and survival curves. In spite of favorable conditions the data clearly indicate that the performance of the distribution box systems was not superior to that of those without distribution boxes, and there is some evidence that the converse is true.

The objective of the study was to determine if alternate arrangements would work as well as the distribution box system, and only the hypothesis that "other" types were equal to the distribution box system was tested. No attempt was made to establish the significance of what appears to be an advantage of the "other" types over the distribution box. Neither were the various schemes that comprise the other types sorted and evaluated to determine their individual merits.

Engineering Significance

Referring to Table 2, it is seen that distribution on level ground is not important, but the high rate of failure on sloping ground indicates need for a method to prevent overloading and failure of one trench before the entire capacity of the field is utilized. On level ground even if one trench receives all of the liquid at first the excess can back up into the other trenches before the first one fails by liquid seeping to the ground surface. However, on sloping ground excessive head may develop in one trench and be relieved by surface seepage before liquid spills back into the other trenches.

The distribution box did not remedy the situation on sloping ground. In fact, rationalization of the observations indicates the distribution box aggravates failure on sloping ground. From a review of the hydraulics and the critical nature of a very slight difference in elevation of the box outlets, it seems likely that in most installations the box serves to divert rather than distribute the liquid.

To prevent high failure rates on slopes a method is needed to prevent excessive build-up of head in any one line. Technically this can be accomplished by efficient division of flow (parallel flow) to match the absorption capacity of each trench or by a method whereby liquid is held in an upper section until it ponds to a danger point and at that level excess is allowed to drain to a lower section (serial distribution). A basic question of the desirability of parallel or serial distribution is posed. If parallel distribution is desirable, a highly efficient method of distribution is needed, and in some cases, a highly complicated method may be needed to match load and absorption capacity of the individual trenches. If serial distribution is equal to, or superior to parallel distribution, the scheme can be greatly simplified.

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APPENDIX A

DESCRIPTION OF SURVEY SITES AND RESULTS

St. Louis, Missouri

Assumption Valley: This subdivision is located in the southern part of the county. It consists of about 75 homes of which 46 were surveyed. This subdivision is one of one, two, and three-year old homes, most of them having three bedrooms and built on large (100') lots. Garbage disposal units were provided as standard equipment in most cases. Some building is still going on here and advertised prices range from $17,000 to $21,000. The entire area is very well maintained and occupancy is by middle class families. As mapped by the U. S. Department of Agriculture(4) and verified at the time of the survey, most of the homes are on a poorly drained Memphis silt loam with a few lots on well drained Genesee silt loam. The terrain is quite hilly and has required extensive modification by cut and fill. Although the systems here were recently installed on the basis of percolation tests, the failure rate is high.

Survey results are as follows:

Type of Distribution	Number of Systems	Number Satisfactory	Failing
Box	31	20	11
Other	15	9	6

Burke City: This subdivision is located in the northern part of the county. It consists of about 400 homes, of which about 270 were surveyed. Homes in this area range from 1 to 25 years of age, with a few new houses being built now. The area has different local characteristics, with some small older homes having substandard conditions (a few still with outside privies) and many four and five-room homes which have recently been modernized, and which are generally well maintained. There are also some areas with two and three-bedroom homes approximately five years old which are very well maintained, and a few recently built homes. Occupancy is by middle class families in general, with the majority of houses in the $10,000 to $15,000 class price range. Terrain here is gently rolling with little apparent modification. The soil is primarily moderately well drained Tama silt loam and except for some few areas with surface drainage problems, soil absorption was fair throughout the area.

One hundred and twelve distribution box systems, all less than 3.5 years old, were compared with the 46 systems in the same

age group, but using other methods of distribution. The survey yielded the following results:

Type of Distribution	Number of Systems	Number Satisfactory	Failing
Box	112	104	8
Other	46	44	2

Capitol Hills: This subdivision is located in the northern part of St. Louis County. It consists of approximately 100 homes, of which 70 were surveyed. Houses in this subdivision are from one to 5 years old and are two and three-bedroom bungalows. These houses are very well maintained and are probably occupied by families in the upper middle class group. Modern appliances are extensively used in the majority of cases. The price of homes in this area is estimated at $15,000 to $25,000. The older homes would fall nearer the lower price, and the newer ranch-style ones with larger lots falling in the higher price range. The soil in this area is Memphis silt loam and Genessee silt loam with poor and good absorption respectively. The topography is rolling. Very little cut or fill was made in this area.

Eleven distribution box systems all less than three years old were found in the subdivision. In the following comparison only the "other" systems in the same age group are used.

Type of Distribution	Number of Systems	Number Satisfactory	Failing
Box	11	11	0
Other	19	15	4

Castle Point: This subdivision is located in the northeast part of St. Louis County. It consists of about 250 homes, of which 172 were surveyed. Homes in this area range from 1 to 25 years of age, with some new homes now being built. The area has very dissimilar local conditions, with some three-room, extremely substandard housing still with outside privies, and having typical slum characteristics, up through some one and two-bedroom houses recently modernized with inside bath; a large number of modern, very small four-room and carport houses on small lots; and a few new five and six-room houses. Sanitary sewers are provided for the new homes now under construction. Occupancy is, in general, by lower and middle class groups. The new three-bedroom homes now being constructed are of simple construction, and sell for about $12,000. The majority of older homes here would be in the "under $10,000 class" at this time.

Soil in this area is Genessee silt loam, black subsoil phase, and Elk silt loam with absorption ranging from fair to poor. The majority of the area is somewhat low lying and surface water drainage is a common problem. The terrain is relatively level and there does not appear to have been much cut or fill during development. Successful soil absorption in this area was influenced by surface water drainage conditions.

Thirty-one distribution box systems all less than three years old were found in the subdivision. In the following comparison only the "other" systems in the same age group are used.

Type of Distribution	Number of Systems	Number Satisfactory	Failing
Box	31	24	7
Other	11	8	3

Concord Meadows: This subdivision is located in the southern part of St. Louis County. It consists of approximately 50 homes of which 30 were surveyed. The houses here are two to three years old and are probably occupied by families in the middle class group. The price of homes in this area is estimated at $15,000 to $20,000. Soil in this area is poorly drained Memphis silt loam. The terrain appears to have been extremely altered, with considerable cut on one side of this one-street area, and fill on the other side. As a result, about 50 percent of the homes have level lots created by cut, and the other 50 percent have level filled front yards, with all back yards all going down, often with a series of terraces, to a small wet weather creek. Possibly because of this, soil absorption was found to be very poor in the vast majority of these cases, and the residents are all anxious to connect their houses to sewers.

The 30 systems, all 2.5 to 3 years old, were evenly divided between boxes and other types of distribution. That neither arrangement is favored under these unfavorable circumstances is shown by the following comparison.

Type of Distribution	Number of Systems	Number Satisfactory	Failing
Box	15	3	12
Other	15	6	9

Crestshire: This subdivision is located in the northern part of the County. It consists of about 40 homes, of which about 30 were surveyed. Homes here are seven to eight years old, with two bedrooms and medium-to-large lots. The terrain is very level

throughout, and apparently little cut or fill was done in development. The houses here are well maintained, and many homes are now being enlarged to provide a third bedroom. The area is occupied by middle class families, with house prices estimated at $12,000. Soil here is Bremer silt loam and Tama silt loam, with fair absorption being found in about all cases. Results are as follows.

Type of Distribution	Number of Systems	Number Satisfactory	Number Failing
Box	13	11	2
Other	19	16	3

Ferguson Acres: This subdivision is located in the northern part of St. Louis County. It consists of approximately 100 homes, of which about 77 were surveyed. As in all of the areas described, records were not available for some cases; descriptions were insufficient to identify locations of some cases; and some homes could not be checked, due to failure to find occupants at home after repeated calls. The homes in this subdivision are about seven years old and are two-bedroom bungalows. These homes are very well maintained and are probably occupied by families in the upper middle class group. Modern appliances are used extensively in the majority of cases. The price of the houses in this area is estimated at $15,000 to $20,000, with the majority in the lower price group. The soil is Memphis silt loam and Bremer silt loam with soil absorption ranging from fair to poor. The topography is gently rolling. In possibly one-third of the cases considerable fill was made in developing front terraces. Other than this, there does not appear to have been much modification of the original terrain.

Only 5 of the 77 examinations were distribution box systems. As with the majority of the failures in this subdivision, the three failing distribution box systems were located in filled terraces. Results are as follows.

Type of Distribution	Number of Systems	Number Satisfactory	Number Failing
Box	5	2	3
Other	72	47	25

Alexandria, Louisiana

Airview Terrace consists of houses one to six years old. Most houses have 6 rooms, 3 bedrooms, and a single bathroom. The area is well maintained and houses are in the $15,000 to $18,000 price range. No cut or fill was needed on the building sites. The soil is sandy clay and even though the site is two miles from the Red River, the ground water fluctuates with the river and at times comes to within a foot of the ground surface. Percolation test records indicate an average rate of approximately 40 minutes per inch.

Type of Distribution	Number of Systems	Number Satisfactory	Failing
Box	10	10	0
Other	6	6	0

Bennett-Daspit subdivision consists of homes built from 2 to 4 years ago. Most houses are fairly well maintained and have either 2 or 3 bedrooms. It is in a middle class residential area with estimated price of the homes $12,000. Sewers are now being put in the area. The land is very level and no cut or fill was needed. There appears to be a marked change of soil in the area although this is not indicated in the soil map. It was found that the sandy clay soil at the southern portion of the area allowed good absorption, but that septic tank performance got progressively worse as the northern part was reached and a much heavier red clay soil was found.

Type of Distribution	Number of Systems	Number Satisfactory	Failing
Box	38	24	14
Other	14	9	5

Cherokee Village subdivision consists of houses built from 1 to 4 years ago. Most houses have 6 large rooms and some have 7 rooms. The majority have 2 full bathrooms. Houses are located on very large lots and the area is occupied by upper income families. Advertised price of homes here is from $20,000 to $25,000. No cut or fill was needed.

Type of Distribution	Number of Systems	Number Satisfactory	Failing
Box	11	6	5
Other	9	5	4

Four Leaf Village subdivision has houses built from 1 to 5 years ago. They are well maintained and have three bedrooms in the majority of cases. It is a middle class residential area with estimated price of homes $12,000 to $15,000. The topography is very level and no cut or fill was needed.

Type of Distribution	Number of Systems	Number Satisfactory	Failing
Box	50	37	13
Other	13	10	3

Gus Gehr is a very small subdivision built during the past 2 years. The houses are well constructed and maintained and all have 3 bedrooms. It is a middle class residential area with estimated house prices $12,000 to $15,000. The area is very level and no cut or fill was needed.

Type of Distribution	Number of Systems	Number Satisfactory	Failing
Box	9	3	6
Other	0	0	0

Henry James subdivision consists of houses built 2 to 3 years ago. Houses are mainly 6 rooms with 3 bedrooms. It is an area of middle income families, with estimated price of homes $14,000 to $16,000. No cut or fill was needed. The entire subdivision is located along one main rural road and is situated so that it receives considerable surface runoff from a large undeveloped tract adjoining it to the rear. The failure rate here was found to be high, probably due to the heavy surface runoff. The residents here are now trying to arrange with the owner of the adjoining property to allow them to build a diversion ditch. No cut or fill was needed, although some of the newer homes have had fill dirt brought in to build up the entire yard level a few inches.

Type of Distribution	Number of Systems	Number Satisfactory	Failing
Box	3	2	1
Other	14	7	7

Jefferson Heights: These homes are 3 bedrooms and carport with semi-attached utility rooms, built from 1 to 5 years ago. Topography of the ground is such that no modification was necessary. They are well kept and the estimated price is $15,000. The area was annexed by the city in November, 1956 and has recently been voted into a sewer district. Streets are now being torn up for the laying of sewers. However, the majority of the residents do not plan to connect to the sewer until they have more trouble with their septic tanks than at present, which is largely confined to the winter season after prolonged heavy rains.

Type of Distribution	Number of Systems	Number Satisfactory	Failing
Box	25	21	4
Other	24	16	8

Martin Park is a subdivision built about one year ago, with many vacant lots still for sale and some building going on now. The homes have 3 bedrooms and carport (no basements) and are very well maintained. The area is completely level and no cut or fill was needed. Most of the homes have 6 rooms and 2 full baths, with many modern appliances. The neighborhood is definitely upper class with homes occupied by doctors, judges, and other professional people. Houses are priced at $15,000 to $20,000 with a few probably even higher. Due to the level terrain, drainage is something of a problem, and the failures observed might have been traceable to surface drainage.

Type of Distribution	Number of Systems	Number Satisfactory	Failing
Box	13	10	3
Other	0	0	0

Penny Acres subdivision consists of homes 1 to 2 years old. Houses have 5 or 6 rooms and most have two bathrooms. No cut or fill was needed. Grading in many cases appears to have left low areas in yards and failures were frequently found. House prices are estimated at $15,000 to $18,000. Records of percolation tests show that sandy red river clay at the surface changes to heavy clay at a depth of 6 feet. The average percolation rate is approximately 6 minutes for one inch of fall.

Type of Distribution	Number of Systems	Number Satisfactory	Failing
Box	21	11	10
Other	1	1	0

Pineridge subdivision consists of homes 2 to 3 years old. They are 6 room, 3 bedroom houses with either 1 or 2 bathrooms. No cut or fill was needed. There is a very slight slope toward a bayou which results in some surface drainage and no failures were noted. This is a middle class income area with houses estimated at $15,000.

Type of Distribution	Number of Systems	Number Satisfactory	Failing
Box	14	14	0
Other	0	0	0

Walnut Grove: These houses are 3 bedroom with carport and semi-attached utility room. The age of the houses varies from a few months to 2½ years, with vacant lots and houses still under construction. They are very well maintained and are occupied by an upper middle class group. Estimated price is $15,000 to $18,000. The contractor-builder states that there is only one lot where the septic tank is not working well. He attributes this one failure to the fact that the trenches sat open quite a while during construction and filled with water. The inspections bore out the fact that this was the only lot with any serious trouble. The entire area is completely level and no cut or fill was needed. Floor slabs on the homes now under construction are being poured on existing ground level. Being so level, drainage is a problem and the roadside ditches and any depressions in yards were found to have water standing in them after each rain, seeping away very slowly. The few complaints concerned this lack of drainage.

Type of Distribution	Number of Systems	Number Satisfactory	Failing
Box	23	22	1
Other	5	5	0

Woodlawn subdivision consists of houses built 1 to 2 years ago. They have 5 rooms and all have either 1½ or 2 full bathrooms and separate utility rooms. The homes are well maintained. The area is very level and has poor drainage . House prices are estimated at $15,000 to $18,000.

Type of Distribution	Number of Systems	Number Satisfactory	Failing
Box	19	13	6
Other	0	0	0

Shreveport, Louisiana

Brookwood subdivision is located in the southern part of Caddo Parish. It consists of approximately 110 homes of which 54 were surveyed. The houses range in age from 1 to 4½ years, with the average being about 2 years. The homes are primarily 2 and 3 bedroom bungalows, occupied by the middle and upper middle class income groups, and are very well maintained. Average price of homes in this area is estimated from $16,000 to $20,000. Soils are Shabuta* and Boswell very fine sandy loams having fair to poor absorption qualities. The terrain has undergone little or no alteration.

Crestwood subdivision is located in the southern part of Caddo Parish. It consists of approximately 19 homes of which 8 were surveyed. The houses range in age from 4 to 5 years with the average being 4½ years. The homes are primarily 2 bedroom bungalows occupied by the upper middle class income groups and are very well maintained. The average price of homes is estimated at $15,000 to $20,000. Soil is Susquehanna very fine sandy loam. The terrain has undergone little or no modification.

Dean Terrace subdivision is located in the southern part of Caddo Parish. It consists of approximately 67 homes, of which 38 were surveyed. The houses range in age from 2½ to 10 years, with the average being about 7½ years. The homes are primarily 2 and 3 bedroom bungalows, occupied by middle and upper middle class income groups, and are very well maintained. Average price of houses is estimated at $15,000 to $25,000. Soil is predominantly Sawyer very fine sandy loam. The terrain has undergone little or no modification..

Dixie Gardens subdivision is located in the southeastern part of Caddo Parish. It consists of approximately 75 homes, of which 38 were surveyed. The houses range in age from 1 to 20 years, the average being about 12 years. The older houses are primarily 2 bedroom dwellings, while the newer houses are both 2 and 3 bedroom bungalows. The homes are occupied by lower and middle class income groups. The average price is estimated at $9,000 to $16,000. Soil is Miller fine sandy loam. The terrain has undergone little or no modification except in areas near the levee where extensive filling has been done.

*Soils in the Shreveport area were identified with the aid of Mr. Bruce Chappin, Soil Scientist, Soil Conservation Service, Shreveport, Louisiana.

W. F. Hyde subdivision is located in the southern part of Caddo Parish. It consists of approximately 12 homes, of which 4 were surveyed. The houses range in age from 2 to 7 years, the average being about 4 years. They are primarily three bedroom bungalows occupied by the upper middle class income groups, and are very well maintained. The average price is estimated at $15,000 to $20,000. Soil in this area is Boswell very fine sandy loam. The terrain has undergone little or no modification.

Live Oak subdivision is located in the southern part of Caddo Parish. It consists of approximately 65 homes, of which 48 were surveyed. The houses range in age from 2 to 8 years, the average being 6 years. The homes are primarily 2 bedroom frame bungalows, being occupied by lower middle and middle class income groups, and are fairly well maintained. The average price is estimated at $12,000 to $14,000. The terrain has undergone little or no modification.

Myer's subdivision is located in the southwestern part of Caddo Parish. It consists of approximately 18 homes of which 6 were surveyed. The houses range in age from 5 to 9 years, the average being about 7 years. The homes are primarily 2 bedroom bungalows, occupied by middle class income groups, and are fairly well maintained. The average price is estimated at $12,500 to $17,500. Soil is Sawyer very fine sandy loam. The terrain has undergone little or no modification.

North Highlands subdivision is located in the northern part of Caddo Parish. It consists of approximately 220 homes, of which 171 were surveyed. The houses range in age from 1 to 9 years, the average being 4 years. The homes are primarily 3 bedroom brick bungalows with attached carports and 2 baths. Modern appliances are used extensively. Homes are occupied by upper middle class income groups, and are very well maintained. The average cost is estimated at $17,000 to $25,000. Soils are Red Bayou and Vian very fine sandy loams. The natural terrain is rolling and some modification by cut and fill was made.

Snyder Gardens subdivision is located in the southwestern part of Caddo Parish. It consists of approximately 30 homes, of which only 5 were surveyed. The houses range in age from 5 to 7 years, the average being 6 years. The homes are primarily 3 bedroom bungalows, occupied by upper middle class income groups, and are very well maintained. The average cost is estimated at $12,500 to $17,500. Soil is Sawyer very fine sandy loam. The terrain has undergone slight modification in some instances.

Wilton Place subdivision is located in the northern part of Caddo Parish. It consists of approximately 42 homes, of which 25 were surveyed. The houses range in age from 1 to 7 years, the average being 5 years. The homes are 2 and 3 bedroom bungalows occupied by middle class income groups, and are very well maintained. Soil is Rosenwald very fine sandy loam. The terrain has undergone little or no alteration.

W. F. Hyde subdivision is located in the southern part of Caddo Parish. It consists of approximately 12 homes, of which 4 were surveyed. The houses range in age from 2 to 7 years, the average being about 4 years. They are primarily three bedroom bungalows occupied by the upper middle class income groups, and are very well maintained. The average price is estimated at $15,000 to $20,000. Soil in this area is Boswell very fine sandy loam. The terrain has undergone little or no modification.

Live Oak subdivision is located in the southern part of Caddo Parish. It consists of approximately 65 homes, of which 48 were surveyed. The houses range in age from 2 to 8 years, the average being 6 years. The homes are primarily 2 bedroom frame bungalows, being occupied by lower middle and middle class income groups, and are fairly well maintained. The average price is estimated at $12,000 to $14,000. The terrain has undergone little or no modification.

Myer's subdivision is located in the southwestern part of Caddo Parish. It consists of approximately 18 homes of which 6 were surveyed. The houses range in age from 5 to 9 years, the average being about 7 years. The homes are primarily 2 bedroom bungalows, occupied by middle class income groups, and are fairly well maintained. The average price is estimated at $12,500 to $17,500. Soil is Sawyer very fine sandy loam. The terrain has undergone little or no modification.

North Highlands subdivision is located in the northern part of Caddo Parish. It consists of approximately 220 homes, of which 171 were surveyed. The houses range in age from 1 to 9 years, the average being 4 years. The homes are primarily 3 bedroom brick bungalows with attached carports and 2 baths. Modern appliances are used extensively. Homes are occupied by upper middle class income groups, and are very well maintained. The average cost is estimated at $17,000 to $25,000. Soils are Red Bayou and Vian very fine sandy loams. The natural terrain is rolling and some modification by cut and fill was made.

Snyder Gardens subdivision is located in the southwestern part of Caddo Parish. It consists of approximately 30 homes, of which only 5 were surveyed. The houses range in age from 5 to 7 years, the average being 6 years. The homes are primarily 3 bedroom bungalows, occupied by upper middle class income groups, and are very well maintained. The average cost is estimated at $12,500 to $17,500. Soil is Sawyer very fine sandy loam. The terrain has undergone slight modification in some instances.

Wilton Place subdivision is located in the northern part of Caddo Parish. It consists of approximately 42 homes, of which 25 were surveyed. The houses range in age from 1 to 7 years, the average being 5 years. The homes are 2 and 3 bedroom bungalows occupied by middle class income groups, and are very well maintained. Soil is Rosenwald very fine sandy loam. The terrain has undergone little or no alteration.

Winter Gardens subdivision is located in the northern part of Caddo Parish. It consists of approximately 60 homes of which 8 were surveyed. The houses range in age from 1 to 6 years, the average being about 4 years. The area has very dissimilar local conditions with several of the older homes approaching substandard characteristics. The majority of the homes surveyed, however, were of the 2 and 3 bedroom bungalow type occupied by middle to upper class income families. The average cost of the better homes in this area is estimated at $12,000 to $20,000. The soil is Rosenwald very fine sandy loam. The terrain has undergone little or no alteration.

Miscellaneous Streets: In an effort to obtain systems in the age group between 10 and 20 years (and older), it was necessary to select cases which were not located in or near subdivisions. Approximately 50% of all of the records on file were of this type; however, due to the renaming and renumbering of the streets only 204 cases were actually located and inspected. In addition, due to the extension of sewer lines about 40% of the surveyed homes had been connected to sewers prior to this investigation, and it was necessary to depend entirely on information contributed by the occupants.

The majority of homes in this category, primarily the older systems, were of the 2 bedroom type occupied by low income families approaching substandard conditions. The homes in the below 10 age group were occupied by low middle class income groups and fairly well maintained. The majority of the homes located near Lakeshore Drive and Curtis Lane are occupied by middle to upper middle class income groups and are very well maintained.

Prices of homes in these areas vary from $9,000 in the older sections to $20,000 in the area near Merriweather and Amelia Roads.

The soils are predominantly Sawyer very fine sandy loam, along with Boswell very fine sandy loam, and some Shabuta very fine sandy loam. The terrain for the most part has undergone very little modification.

APPENDIX B

SAMPLE CALCULATIONS

Standard Deviation

$$s^2 = \bar{p}\,\bar{q}\left(\frac{1}{n} + \frac{1}{n'}\right)$$

$$\bar{p} = \frac{pn + p'n'}{n + n'}$$

where: p = ratio $\frac{\text{failed}}{n}$ for distribution box systems

$q = 1 - p$

n = total number of distribution box systems

p', q' and n' have same meaning for other systems

Assumption Valley

$$\bar{p} = \frac{(.40)\,(15) + .35\,(31)}{15 + 31} = 0.366$$

$$\bar{q} = 1 - 0.366 = 0.634$$

$$s^2 = (0.366)\,(.634)\left(\frac{1}{15} + \frac{1}{31}\right) = 0.02297$$

$s = 0.15$
or standard deviation = 15 percent

Chi-square

4-fold table

Assumption Valley

	Satisfactory	Failed	Total
Distribution Box	20	11	31
Other	9	6	15
	29	17	46

$$\chi^2 = \frac{\left(\left|(6)\,(20) - (9)\,(11)\right| - \frac{46}{2}\right)^2 (46)}{(29)(17)\,(31)\,(15)}$$

$$\chi^2 = .002$$

Reject hypothesis that there is no significant difference in performance if $\chi^2 > 3.84$

Chi-square

Tabulated data

Septic Tank Capacity - St. Louis

Capacity Gals. per Person	Number of Observations D.B. x_1	Other x_2	Total N	$\frac{(x_2)^2}{N}$
0 - .99	45	56	101	31.050
100 - 199	130	99	229	42.799
200 - 299	35	41	76	22.118
300 - 599	5	0	5	0
Total	Σ 215	Σ 196	Σ 411	Σ 95.967

$$\bar{p} = \frac{\Sigma x_2}{\Sigma N} = \frac{196}{411} = 0.477$$

$$\bar{q} = (1-\bar{p}) = 1 - 0.477 = 0.523$$

$$\bar{p}\,\Sigma x_2 = 0.477 \times 196 = 93.492$$

$$\chi^2 = \frac{\Sigma \frac{(x_2)^2}{N} - \bar{p}\,\Sigma x_2}{\bar{p}\,\bar{q}} = \frac{95.967 - 93.492}{0.477 \times 0.523}$$

$$\chi^2 = \frac{2.475}{0.249} = 9.94$$

Probability "P", Fischer's Method

Crestshire	Satisfactory	Failed	Total
Distribution Box	11	2	13
Other	16	3	19
	27	5	32

$$P_2' = \frac{(27)!\,(5)!\,(19)!\,(13)!}{(32)!\,(11)!\,(2)!\,(16)!\,(3)!}$$

Factoral	Log Factoral	Factoral	Log Factoral
32	35.420	27	28.037
11	7.601	5	2.079
2	.301	19	9.794
16	13.321	13	17.085
3	.778	Total	56.995
Total	57.421		
Minus	56.995		
Difference	0.426	Anti-log 0.426 = 2.67	

$$P_2' = \frac{1}{2.67} = 0.375$$

For P_o and P_1 keep margin totals constant and adjust boxes.

		Satisfactory	Failed	Total
P_1	Distribution Box	12	1	13
	Other	15	4	19
		27	5	32

Crestshire (Continued)

Factoral	Log Factoral
32	35.420
12	8.680
1	0.000
15	12.116
4	1.380
Total	57.596
Minus	56.995
Difference	.601

Anti log 0.601 = 3.99

$$P_1 = \frac{1}{3.99} = 0.251$$

P_o

	Satisfactory	Failed	Total
Distribution Box	13	0	13
Other	14	5	19
	27	5	32

Factoral	Log Factoral
32	35.420
13	9.794
14	10.940
5	2.079
Total	58.233
Minus	56.995
Difference	1.238

Anti log 1.238 = 17.3

$$P_o = \frac{1}{17.3} = 0.058$$

$P = \Sigma P_i = P_2 + P_1 + P_o$

$P = 0.375 + 0.251 + 0.058$

$P = 0.68$

Combination of Probabilities from 4-fold Tables

St. Louis

$\mu = -2\Sigma \ln P_i = -4.605 \Sigma \log P_i$

μ has a χ^2 distribution

Subdivision	P	log P
Assumption Valley	.34	0.532 - 1
Burke City	.64	0.806 - 1
Capitol Hill	.14	0.146 - 1
Castle Point	.78	0.892 - 1
Concord Meadows	.22	0.342 - 1
Crestshire	.68	0.832 - 1
Ferguson Acres	.26	0.415 - 1
	$\Sigma \log P$ =	3.965 - 7

$\mu = (4.605)\ (3.035) = 14.0$

From table of χ^2 with $7 \times 2 = 14$ d f

$P = 0.46$